Procedures in Mathematical Problems and Video Games

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Video game use is widespread among all age groups, from young children to older adults. The wide variety of video game genres, which are adapted to all tastes and needs, is one of the factors that makes them so attractive. In many cases, video games function as an outlet for stress associated with everyday life by providing an escape from reality. The recreational aspect of video games is more important than the educational aspect. However, the students were not aware of using the problem-solving procedures they learned at school to solve different challenges in the video games. Furthermore, overcoming video game challenges stimulates positive emotions as opposed to the negative emotions generated when solving mathematical problems.

mathematical problem-solving video games

1. Introduction

Current technological developments emerge in all social, cultural, and educational contexts. Among these developments, digital whiteboards or didactic software are examples of applications and hardware designed for the educational context. However, there are also digital elements that, despite not being designed for the teaching–learning process, have been used for this purpose. In light of this, video games could be considered based on the same essence as traditional games. McGonigal [1] states that a video game must be based on the premise of overcoming a challenge and being motivated to do so. Therefore, when interacting with these recreational applications, the individual must: (a) analyse the challenge that appears before them and determine what its purpose is; (b) analyse which elements in the game represent support (power-ups) or which elements are negative (enemies, traps, or penalties); (c) discover how to progress or gain experience; (d) consider action sequences by trial-and-error exercises; and (e) put decision-making skills into practice [2]. A careful analysis of the previously mentioned skills reveals that they are similar to those used in problem-solving.

Based on this, problem-solving is one of the most relevant areas in logical–mathematical knowledge. In fact, problem-solving can be applied to the field of mathematics as well as to aspects of daily life: when people encounter situations that require a solution in their daily lives, they unconsciously apply the problem-solving method they learned in school. In this manner, mathematical competence is developed through problem-solving exercises. According to Gorgorió and Albarracín [3]:

Mathematical competence is the ability to use mathematical knowledge in a cross-cutting manner in mathematical and non-mathematical situations and contexts. Mathematical competence goes beyond procedural knowledge; it is

manifested in the use of conceptual knowledge in different practical situations.

In view of this definition of mathematical competence, it could be stated that video games are included in these non-mathematical contexts. Various studies describe the use of these elements in the classroom—for example, using the Angry Birds video game to develop mathematical knowledge [4][5][6] or physical knowledge [7][8][9][10][11].

2. Problem-Solving

Problem-solving could be considered one of the most important curricular activities in all the stages of a country's educational system. Analysing the current legislation, one can see that, in all cases, problem-solving is oriented towards problems in children's daily lives. Focusing on Spain (whose legislation stipulates that problem-solving be present from the earliest stages of education), self-confidence, the capacity for initiative, and problem-solving are developed from early childhood education onwards [12]. In primary education, problem-solving competencies are also developed within the field of mathematics, together with others, such as reading, reflection, planning processes, establishing resolution strategies, and designing and evaluating procedures [13]. In both stages, problem-solving is based on the development of different skills that allow students to address the situation and/or problem while developing skills related to personal development, personal autonomy, confidence, and motivation to overcome situations in their daily lives.

The logical–mathematical skills to be developed are established sequentially through a series of phases. As a result of these phases, a methodology for solving mathematical problems that is applicable to any situation is established. One of the most well-described and frequently used methodologies is that of Polya [14], which outlines four phases to pose and solve a problem through a series of questions set out in a method (**Table 1**).

Table 1. Polya's problem-solving phases.

Phases	Questions
Understanding the problem	What is the unknown? What data do I have? What is the condition? Is it enough to find the unknown? Is it redundant, contradictory, or insufficient?
Devising a plan	Have I seen this problem before? Do I know of any similar problems?
Carrying out the plan	Am I sure that each step is correct? Can I prove that the step is correct?
Looking back	Can I check the result and the reasoning? Can I derive the solution differently?

Source: own elaboration based on Polya [14].

References

Mason, Burton, and Stacey [15] described another method of phased problem-solving, which is divided into three phases—entry, attack, and review. As with the previous method, in each of its phases, a series of questions are posed that allow the individual to progress (**Table 2**).

Table 2. Summary of Mason, Burton, and Stacey's problem-solving phases.

Phases	Processes	Issues or Propositions	States
Entry	Specialising	What do I KNOW? What do I WANT? What can I INTRODUCE?	STUCK!
Attack		CONJECTURE	
	Generalising	Try (Attempt) Check and distrust (Maybe) But why?	AHA!
Review		CHECK the resolution REFLECT on the key ideas and key moments GENERALISE to a wider context	

Source: Own elaboration based on Mason et al. [15].

Within the description of the method presented by Mason et al. [15], as well as the phases, there are processes such as specialising—typical of the entry and attack phases—and generalising—typical of the attack and review phases. The method introduces the concepts of STUCK! and AHA!—concepts related to the manner of dealing with problem-solving and the learning possibilities that can be extracted from solving the problem.

Being in the STUCK! phase leads to many cases of frustration and a lack of motivation to move forward. Recent studies [16] introduce a new phase in problem-solving methods, in which the identification and control of emotions that arise when solving a problem plays an important role. Del Valle [17] indicates that the main emotions that students experience when solving a mathematical problem are frustration and confusion, which are negative emotions. Managing negative emotions, such as confusion, can lead to positive emotions that help with solving the problem. According to Caballero, Blanco, and Guerrero [18], it is necessary to introduce emotional aspects as well as cognitive aspects in mathematical problem-solving. By doing so, it can develop techniques, such as relaxation or breathing techniques, that allow us to transform negative emotions, such as anxiety, into positive emotions. Hannin and Nieuwenhoven [19] found a reduction in negative emotions in students who had developed cognitive and emotional aspects versus those who had only received training in problem-solving, although the cognitive levels were equivalent. Therefore, it is necessary to take into account cognitive and emotional changes as a whole, rather than individually, to understand students' performance when solving mathematical problems [20]. These changes move students from the STUCK! phase to the AHA! phase.

3. Video Games for Problem-Solving

1. McGonigal, J. Reality Is Broken: Why Games Make Us Better and How They Can Change the World; Penguin: Sidney, Australia, 2011.
2. Revuelta, F.I.; Guerra, J. ¿Qué aprendo con videojuegos? Una perspectiva de meta-aprendizaje del videojugador. Rev. Educ. Distancia 2012, 33, 1–25.
3. Gorgorió, N.; Albarracín, L. Mathematical knowledge prior to the Initial Education of Teachers: The [illegible] eacher: [illegible]
4. [illegible] Study [illegible] 6, [illegible]
5. [illegible] ation.
6. Tokac, U.; Novak, E.; Thompson, C.G. Effects of game-based learning on students' mathematics achievement: A meta-analysis. J. Comput. Assist. Learn. 2019, 35, 407–420.
7. Anderson, J.; Barnett, M. Using Video Games to Support Pre-Service Elementary Teachers Learning of Basic Physics Principles. J. Sci. Educ. Technol. 2011, 20, 347–362.
8. Croxton, D.; Kortemeyer, G. Informal physics learning from video games: A case study using gameplay videos. Phys. Educ. 2017, 53, 015012.
9. de Aldama, C.; Pozo, J.-I. Do you want to learn Physics? Please play Angry Birds (but with epistemic goals). J. Educ. Comput. Res. 2020, 58, 3–28.
10. Pitman, C. Teaching with Portals: The Intersection of Video Games and Physics Education. Learn. Landsc. 2013, 6, 341–360.
11. Ullman, T.D.; Spelke, E.; Battaglia, P.; Tenenbaum, J.B. Mind Games: Game Engines as an Architecture for Intuitive Physics. Trends Cogn. Sci. 2017, 21, 649–665.
12. Ministerio de Educación y Ciencia. Orden ECI/3960/2007, de 19 de Diciembre, por la que se Establece el Currículo y se Regula la Ordenación de la Educación Infantil. Boletín Oficial del Estado, 2008. Available online: https://www.boe.es/eli/es/o/2007/12/19/eci3960 (accessed on 13 December 2021).
13. Ministerio de Educación, Cultura y Deporte. Real Decreto 126/2014, de 28 de Febrero, por el que se Establece el Currículo Básico de la Educación Primaria. Boletín Oficial del Estado 2014. Available online: https://www.boe.es/eli/es/rd/2014/02/28/126 (accessed on 13 December 2021).

14. Polya, G.; Zugazagoitia, J. Cómo Plantear y Resolver Problemas, 15th ed.; Trillas: Mexico City, Mexico, 1989; ISBN 9682400643.
15. Mason, J.; Burton, L.; Stacey, K. Pensar Matemáticamente, 2nd ed.; Labor: Barcelona, Spain, 1992; ISBN 8433551396.
16. Quintanilla Batallanos, V.A.; Gallardo Romero, J. Identificar experiencias emocionales para mejorar la comprensión en matemáticas. Uno Rev. De Didáctica De Las Mat. 2020, 88, 24–33.
17. Di Leo, I.; Muis, K.R.; Singh, C.A.; Psaradellis, C. Curiosity… Confusion? Frustration! The role and sequencing of emotions during mathematics problem solving. Contemp. Educ. Psychol. 2019, 58, 121–137.
18. Caballero, A.; Blanco, L.J.; Guerrero, E. Problem solving and emotional education in Initial Primary Teacher Education. EURASIA J. Math. Sci. Technol. Educ. 2011, 7, 281–292.
19. Hanin, V.; Van Nieuwenhoven, C. Developing an expert and reflexive approach to problem-solving: The place of emotional knowledge and skills. Psychology 2018, 9, 280–309.
20. Trezise, K.; Reeve, R.A. Cognition-emotion interactions: Patterns of change and implications for math problem solving. Front. Psychol. 2014, 5, 840.
21. Hernández-Sabaté, A.; Albarracín, L.; Calvo, D.; Gorgorió, N. EyeMath: Identifying Mathematics problem solving processes in a RTS video game. In Proceedings of the Games and Learning Alliance: 5th International Conference, GALA 2016, Utrecht, The Netherlands, 5–7 December 2016; Springer: Cham, Switzerland, 2016; pp. 50–59.
22. Bavelier, D.; Green, C.S.; Pouget, A.; Schrater, P. Brain plasticity through the life span: Learning to learn and action video games. Annu. Rev. Neurosci. 2012, 35, 391–416.
23. Blumberg, F.C.; Rosenthal, S.F.; Randall, J.D. Impasse-driven learning in the context of video games. Comput. Hum. Behav. 2008, 24, 1530–1541.
24. de Aguilera, M.; Mendiz, A. Video games and education. Comput. Entertain. 2003, 1, 1–10.
25. Tan, D.Y.; Cheah, C.W. Developing a gamified AI-enabled online learning application to improve students' perception of university physics. Comput. Educ. Artif. Intell. 2021, 2, 100032.